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SEAKEEPING AND MOTION CONTROL TRAILS OF SSP KAIMALINO IN SEA ST--ETC(U)
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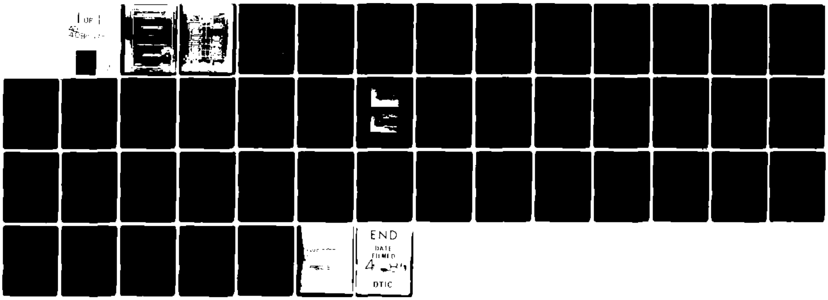

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) DTNSRDC-81/015	2. GOVT ACCESSION NO. AD-A096 116	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) SEAKEEPING AND MOTION CONTROL TRIALS OF SSP KAIMALINO IN SEA STATES 4 AND 5.		5. TYPE OF REPORT & PERIOD COVERED Formal
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) James A. Fein		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Work Unit 1100-200 Task Area SF 43411211 Task 19424
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command Washington, D.C. 20362		12. REPORT DATE (11) February 1981
		13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) (12) 46 (16) F43411 (17) SF43411211		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Full-Scale Trials
Motion Control
Small Waterplane Area Twin-Hull Ships

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Full-scale seakeeping trials were conducted on the Small Waterplane Area, Twin-Hull (SWATH) ship designated Semi-Submerged Platform (SSP) KAIMALINO. The ship has a displacement of 220 tonnes and a length of 26.7 meters. Trials were conducted in Sea States 4 and 5 at various headings and a full range of speeds. The effect of automatic motion

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control was evaluated. Measurements were made of motions and accelerations and the seaway. Results are presented in significant value form. The results establish the motion characteristics of KAIMALINO and illustrate the good seakeeping characteristics inherent in SWATH ship designs both with and without automatic motion control.

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ABSTRACT

Full-scale seakeeping trials were conducted on the Small Waterplane Area, Twin-Hull (SWATH) ship designated Semi-Submerged Platform (SSP) KAIMALINO. The ship has a displacement of 220 tonnes and a length of 26.7 meters. Trials were conducted in Sea States 4 and 5 at various headings and a full range of speeds. The effect of automatic motion control was evaluated. Measurements were made of motions and accelerations and the seaway. Results are presented in significant value form. The results establish the motion characteristics of KAIMALINO and illustrate the good seakeeping characteristics inherent in SWATH ship designs both with and without automatic motion control.

ADMINISTRATIVE INFORMATION

The work described here was performed for the Small Waterplane Area, Twin-Hull (SWATH) Ship Development Office (Code 1110) of the Systems Development Department of the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). Funding was provided by Work Unit 1100-200. The funding source was the SWATH Ship Exploratory Development Program under the Ships, Subs, and Boats Program, Task Area SF 43411211, Task 19424. The Program Manager was Mr. S!uier, Code 031R, of the Naval Sea Systems Command, Washington, D.C.

INTRODUCTION

SWATH ships offer the potential for excellent motions and sustained speed capability in a seaway. The SWATH concept, derived from conventional catamarans and ocean oil-drilling platforms, combines the speed and large deck area of the conventional catamaran with the seakindliness and platform stability of the drilling rig. A SWATH ship consists of two streamlined, submerged hulls that are torpedo-like in shape, each of which is connected to an above-water structural box by one or two thin struts. Propellers located behind each hull provide the propulsive force. Control surfaces on the lower hulls provide stability and can be activated to control trim and further reduce motions when the ship is underway.

A typical SWATH design would have only 20 percent of the waterplane area of a conventional monohull. The reduced waterplane area and redistribution of buoyant volume into submerged hulls reduce the amount of force transmitted to the ship by waves. This decoupling of the ship from wave excitation forces is the fundamental idea behind the SWATH concept. The reduced waterplane area also allows the

SWATH ship to be more responsive in the vertical plane to the forces generated by control surfaces than would a conventional hull.

The U.S. Navy's development of the SWATH concept began in 1970 with the design of Semi-Submerged Platform (SSP) KAIMALINO by T.G. Lang of the Naval Ocean Systems Center (NOSC) in California and the MODCAT program at DTNSRDC. MODCAT was renamed SWATH (Small Waterplane Area, Twin-Hull) in 1972 to differentiate the concept from conventional catamarans.

SSP KAIMALINO has undergone extensive trials beginning in 1974. The first series of trials was conducted in 1975 and included powering, structural loads, control response, maneuvering, and seakeeping.[1-3*]

In November 1976, low-speed trials were conducted by DTNSRDC on SSP KAIMALINO to obtain bending moments in beam seas. In conjunction with that effort, the motions, bow vertical acceleration, and seaway were measured at all headings at the nominal speed of 5 knots. These results (Reference 4) provided information about SSP KAIMALINO motions in a high Sea State 5 at low speed. The ship had been modified prior to these experiments by the addition of inboard buoyancy blisters on the lower hulls.

This report describes an extensive series of seakeeping trials conducted off Kauai and Oahu Islands in January 1979. Experiments were conducted in head, bow, beam, quartering, and following seas at craft speeds of 0, 3.5, 7, 10, and 15.5 knots in a seaway corresponding to Sea State 4 or 5. The measured significant wave height varied from 2.0 to 3.2 m. Measurements were made of the seaway, pitch, roll, vertical motion near the center of gravity (CG), control surface deflections, vertical and horizontal accelerations at the stable table, and vertical acceleration in the pilot house. These data, obtained on the only currently existing SWATH ship in the United States, provide a record of the motion characteristics of a SWATH ship and the effectiveness of control. The data should be useful in evaluating analytical prediction tools and model experimental results. This report presents the data in the form of significant values.

*A complete listing of references is given on page 37.

SHIP DESCRIPTION

SSP KAIMALINO is the first SWATH ship built in the United States. Designed by T.G. Lang (Reference 5) in 1970, it was intended as a workboat for the NOSC Hawaii Laboratory. It has proven valuable both as a workboat and as a platform for demonstrating the seakeeping advantages of the SWATH concept. Constructed in 1973 by the Curtis Bay Coast Guard Shipyard in Baltimore, Maryland, the ship was modified at Dillingham Shipyard in Hawaii by the addition of displacement-increasing buoyancy blisters in 1975. The current displacement is 220 tonnes.

The particulars of SSP KAIMALINO as tested are presented in Table 1. As shown in Figure 1, the ship consists of two cylindrical lower hulls connected to the upper box by two struts per hull. Buoyancy blisters are located on the inboard side of each hull, extending with constant thickness from approximately 7 to 16 m aft of the nose and terminating at 21 m aft of the nose. Tapered, all-movable control fins (called canards) are located inboard just aft of the noses. A constant chord, flapped hydrofoil spans the space between the hulls aft of amidships. Rudders are mounted in the propeller slipstream behind each hull. The forward struts increase in chord and thickness from a point just below the waterline to the connection to the box; the aft struts also increase in thickness as the box is approached. Both starboard struts are outfitted with spray rails well above the waterline that help in deflecting sheets of water that might climb the struts in waves. The above-water box is flat bottomed except for slanted, shaped sections on the forward end. These sections tend to cushion slams in head seas.

Higdon (Reference 6) describes the automatic motion control system designed to reduce motions in all sea conditions. The system uses the forward canards and the stern foil flaps to minimize pitch and roll motions. Heave is not minimized, but it can be controlled so as to minimize relative motion with respect to the wave in order to reduce water contacts in low encounter frequency situations, such as following seas. This control mode relies on pressure (height) sensors located in the underwater hulls in conjunction with minimized inertial pitch and roll. Heading control is maintained by the rudders keyed to a yaw-rate gyroscope.

SSP KAIMALINO is outfitted with two 1660-kW (2230-hp) gas turbine engines in the upper box that drive controllable pitch propellers through a chain drive

system. SSP KAIMALINO reached 25 knots in 1974 before the blisters were added. Current torque limitations on drive train components reduce the top speed to about 18 knots.

DESCRIPTION OF INSTRUMENTATION AND MEASUREMENTS

Measurements were made of ship motions, accelerations, and the seaway. Impact pressures and strains were also measured, but were not analyzed because there were insufficient impacts. The transducer locations are shown in Figure 1. Pitch, roll, vertical acceleration, surge acceleration, and sway acceleration were measured at the stable table located on the craft centerline as close to the longitudinal center of gravity (LCG) as was practical, as indicated in Figure 1. Vertical acceleration was also measured in the pilot house (Frame 5). An ultrasonic displacement transducer measured relative bow motion about 3 ft (1 m) forward of the craft bow; however, this transducer was not operational for most of the trial. Wind speed and direction were measured by an on-board anemometer. A calibrated speed log monitored ship speed. A free floating buoy which telemetered wave data back to the ship for recording measured the seaway. The buoy was launched and recovered from the SSP for selected low-speed runs. When the buoy was tied on deck, it provided a ship vertical motion measurement as shown in Figure 1.

TRIAL PROGRAM AND PROCEDURE

The SSP trials program reported in this document was conducted over four days in Sea States 4 and 5. Runs were made in head, bow, stern quartering, following, and beam seas for a range of speeds and control strategies.

Seaway conditions for a location near the trial area were predicted by the Fleet Numerical Global Model. This model uses worldwide pressure data to predict wave conditions at a series of mesh points located in the oceans. These predictions for 24 hr into the future were very useful for trials planning. Knowledge of wave height, modal period, and primary direction of the wave energy was essential since an objective of the trials was to explore resonant period excitation and zero encounter frequency conditions. Seaway conditions and predictions are listed in Table 2. The trial run conditions, combinations of speed, wave heading, and control option are summarized in Table 3. A total of 50 conditions were explored, providing a wide base of information on the seakeeping of the SSP with and without control in reasonably heavy seas. The 24-hr wave and wind predictions given in Table 2

show good agreement with actual trial conditions, considering the fact that the prediction location was about 80 mi north of the trial area and that the presence of nearby islands could have had a modifying effect. The wave height predictions represent an overall total that also could be broken down by wave direction. The predictions for modal periods of the wave spectra are not given here because the prediction model reports modal values in 2.3-sec increments, not as exact values. The predicted modal values were always at the time increment closest to the measured modal period. Similarly, wave direction was given in 30-deg increments. Nevertheless, these predicted values were useful in planning the trials.

Each day the waves were reasonably consistent over the trial period so all the runs of a given day can be considered to have been conducted in essentially the same sea condition. The sea spectra for selected runs were evaluated from buoy data measurements obtained near the craft. The seaway was observed visually to be substantially unidirectional, although there were no directionality measurements to confirm this.

In conformity with the procedure for the other trials, the ship was ballasted in calm water at zero speed to zero trim and heel condition each day before tests began. Draft readings were made and recorded, along with water temperature and specific gravity in order to determine displacement. Ship displacement was constant throughout the trial even though draft was increased on the last day to compensate for the lack of a port buoyancy module. All trials were run in an area where the water depth was at least 300 m (990 ft).

Figure 2 shows SSP KAIMALINO undergoing trials. In preparation for each particular run, the ship was steadied on course at roughly the desired speed. The speed varied slightly due to wind and wave conditions. The course was set to maintain a constant heading to the predominant seaway as determined by observations. Once the heading and speed were set, the specified automatic or manual control option was implemented for the run, and the data collection began. Collection time was governed by the need for sufficient encounters at the given speed, and heading and varied from 20 to 25 min. No changes in manual control surface deflection or propulsion settings were made during the data collection period.

ANALYSIS OF DATA

The motions, accelerations, and wave height were analyzed to obtain significant values and power spectra. Significant values which are defined as the average of the one-third highest oscillations were generated by a histogram analysis of the digitized tape segment for each run's encounters. Single positive and negative amplitudes were analyzed separately and then combined. Power spectral density functions were generated by Fourier analysis of the data. These power spectra were computed for pitch, roll, vertical motion, vertical acceleration, surge acceleration, sway acceleration, and pilot house vertical acceleration. Single amplitude histogram distributions were generated for the same channels. Significant values obtained from the area under power spectra agreed well with those obtained from the histograms. The motion spectra and wave spectra are reported in Reference 7.

DISCUSSION OF RESULTS

The significant values for pitch, vertical motion, stabilized vertical acceleration and roll, all normalized by significant wave height, $H_{1/3}$, are given in Figures 3 through 22 as a function of Froude Number. The results from the low-speed seakeeping trials of 1976 described in Reference 4 are given for pitch, vertical acceleration, and roll where available. In general, the 1976 results agreed well with the trends of the current results. The effect of motion control is shown in all figures. The normal control mode was designed for platforming in head seas and acts to reduce pitch and roll motions. The heave contour mode, which augmented the normal control mode in following seas, generated some vertical motion to follow or "contour" the waves. Such a mode helps avoid slamming and propeller emergence in following seas by keeping the ship at roughly a constant mean depth.

HEAD SEAS

Figures 3 through 6 contain the SSP responses in head seas. Pitch in Figure 3 decreases as speed increases but there is no data between 10 and 14 knots which is the region of the wave drag hump. The pitch damping due to the control surfaces increases as speed increases. The 1976 data agrees very well with the more recent results. The normal (pitch and roll platforming) control mode shows a reduction

in pitch of over 30 percent at 7 knots full scale (Froude Number of 0.24), almost 50 percent at 10 knots (Froude Number of 0.34), and about 80 percent at the top speed of 15.5 knots (Froude Number of 0.52). The large reductions in motions illustrate the benefits of automatic control. The repeat control points at the two higher speeds show good agreement for pitch motion. All cases were conducted in a Sea State 5, but the repeat was run after the port blister was removed. Vertical motion in Figure 4 shows a reduction as speed increases and little difference due to normal control since heave was not being controlled in the control mode. The induced heave due to the contour control mode is indicated by the lone point at the Froude Number of 0.34. The vertical acceleration data (Figure 5) illustrates the effect of the heave induced when in the heave contouring mode and the effect of the blisters in the controlled conditions at the higher speeds. The cases without a port blister show a lower acceleration level than the cases with both blisters. Roll (Figure 6) is small in head seas, except at zero speed where the coupling between pitch, heave, and roll appears to be large. Again, no data are available between 10 and 14 knots, the region of the wave drag hump where speed is unstable. The control system for roll is very effective above a Froude Number of 0.24 (7 knots). Roll is reduced by 50 percent at 10 knots and by 80 percent at the top speed. Slamming occurred at the high speed without automatic control; but, by manually trimming the bow up about 4 deg, slam-free operation was possible. At other speeds without controls and at all speeds with automatic control, slams were rare (no more than one every 3 min) and not a problem. Static-induced trim was needed to reduce slamming only in the high-speed, uncontrolled case. Severe pitch motions were not noted for any head sea case.

BOW SEAS

The bow seas results are given in Figures 7 through 11. Pitch in Figure 7 is of roughly the same magnitude as the head sea values. Control tends to reduce pitch motion by about 50 percent at the higher speeds. Vertical motion in Figure 8 shows the trend of decreasing as speed increases. For both vertical motion and acceleration (Figure 9), the repeat points at the high speed have higher values for the case with two blisters than for the single blister run for both controlled and uncontrolled conditions indicating that the blisters strongly affect heave. Figure 10 gives the significant roll in bow seas. The control system is again shown to be

effective in reducing roll. Slamming occurred only at the highest speed when controls were off; even then only five light wave contacts with the upper hull were noted during the 1/2-hr run time.

BEAM SEAS

The beam seas results are given in Figures 11 through 14. Beam sea pitch decreases with forward speed up to about 7 knots, where it starts to increase and continues through hump speed. Pitch is reduced by half at the higher speeds when control is employed. Pitch in beam seas could be due to the large control surface area aft of the LCG that produces an appreciable pitch moment when excited by beam waves. Vertical motion in Figure 12 is relatively constant with speed and is not affected much by the use of control. Vertical acceleration in Figure 13 shows a clear trend with some scatter. The roll amplitudes in Figure 14 demonstrate the effect of control dramatically. It is clear that adding the heave contour control mode, while reducing roll to some extent, is not as effective as the normal mode alone, which reduces roll by 80 percent at 15.5 knots. The repeat point at a Froude Number of 0.34 shows that the loss of the blister resulted in little change in the roll magnitude. No slamming was noted for this heading, but occasional wave slaps occurred at all speeds when automatic control was not employed.

STERN QUARTERING SEAS

The stern quartering seas results are presented in Figures 15 through 18. Pitch (Figure 15) in stern quartering seas demonstrates the benefits of automatic motion control as motions are reduced by over 50 percent at the higher speeds. The cases with only one blister result in less pitch motion for both controlled and uncontrolled cases. That difference could be due to the differing sea conditions on the final trial day, when there was only one blister. The heave contour control mode was used in addition to pitch/roll control in stern quartering seas and it produced a significant reduction in vertical motion as seen in Figure 16, though not much change in vertical acceleration (Figure 17). Roll (Figure 18) is greatly reduced by the control system, as much as 70 percent at the top speed. The repeat point indicates that the blister had little effect on roll. It should be noted

that, at zero speed, data could not be collected since the SSP would not hold the stern quartering heading. No slamming was noted for this heading at any speed.

FOLLOWING SEAS

In following seas, the encounter frequency of some of the wave energy approached zero. That is, the ship was moving at nearly the same speed as the predominant waves. This led to highly tuned conditions where motion varied greatly with speed and with the frequency content of the sea. This is apparent in Figures 19 through 22. In Figure 19 the significant pitch varies greatly with speed. At the Froude Number of 0.34 the motions appear to be small though they are larger at speeds above and below that point. Large reductions in pitch are evident at the Froude Number of 0.24 (7 knots), which is a good indication that motion control does not require high speeds to be effective. Pitch motions are higher in following seas than in head seas, but the frequency of the motion is much lower. The heave contour mode was utilized in addition to the normal control mode that reduced pitch and roll. No slams or propeller broaching were noted either with or without control. There is not enough vertical motion data in Figure 20 to determine trends, although vertical acceleration results in Figure 21 show that the addition of the contour control mode reduces accelerations somewhat. Figure 22 gives the roll magnitude in following seas, which is low except at the high speed, where the encounter frequency of the maximum wave energy is exciting the natural period of the craft in roll. The control system is capable of reducing the roll at high speed by 90 percent.

Overall, the motions in Sea States 4 and 5 were quite low when motion control was utilized. Slamming was minimal in all conditions except in head seas at high speed where trimming the craft by control action greatly reduced the occurrence of impacts. The significant value ratios in the figures provide a good indication of the seakeeping qualities of the SSP; but further understanding of the motion characteristics will require study of the spectral density functions for the motions and the waves.

CONCLUSIONS

1. The control system of SSP KAIMALINO is capable of reducing motion significantly at all headings. In head, bow, and beam seas, a normal control mode which

minimized pitch and roll motions is utilized. In stern quartering and following seas, the normal mode is used in conjunction with a control mode that contours the waves by inducing heave to maintain a constant height over the waves. This combination of controls helps prevent propeller broaching in long encounter period conditions. Motions can be appreciably reduced at speeds of 7 knots (Froude Number of 0.24) and above. The current analog control system with fixed gains appears adequate for the SSP, although motion characteristics and control effectiveness do vary with speed.

2. The blisters mounted on the SSP lower hulls to increase displacement do not have a significant influence on SSP KAIMALINO pitch and roll motions. The absence of one blister did not significantly affect the magnitude of the responses or the trends for pitch and roll, although heave motion was affected in bow seas.

3. Slamming did not occur in bow, beam, stern quartering, or following seas either with or without control. In head seas, impacts at high speed without automatic control were effectively eliminated by dynamically trimming the ship bow up by manual control surface deflections. This lack of slamming is significant, because in Sea State 5, the wave heights were large compared to the bridging structure clearance of the ship which was 1.8 m.

4. The SSP did not exhibit any problems in a Sea State 5 nor any conditions that required slowing down or changing heading (except inability to maintain a stern quartering heading at zero speed). Motion characteristics even without control did not induce discomfort or difficulties for the crew.

ACKNOWLEDGMENTS

The author would like to acknowledge the assistance of personnel of the Naval Ocean Systems Center, Hawaii Laboratory, in particular Robert Pace, in the conduct of these trials. The Kentron, Inc. crew responsible for operating SSP KAIMALINO are thanked for their cooperation. In addition, from DTNSRDC, Gordon Minard and Aden Langford provided valuable assistance in obtaining the data, Michael Davis aided in the processing of the results, and Joyce Voelker and Susan Bales along with the Fleet Numerical Oceanographic Center, Monterey, California, provided the predictions of wave environment. Finally, Donald Higdon of SEACO, Inc. was invaluable for his knowledge of the control system and seakeeping in general.

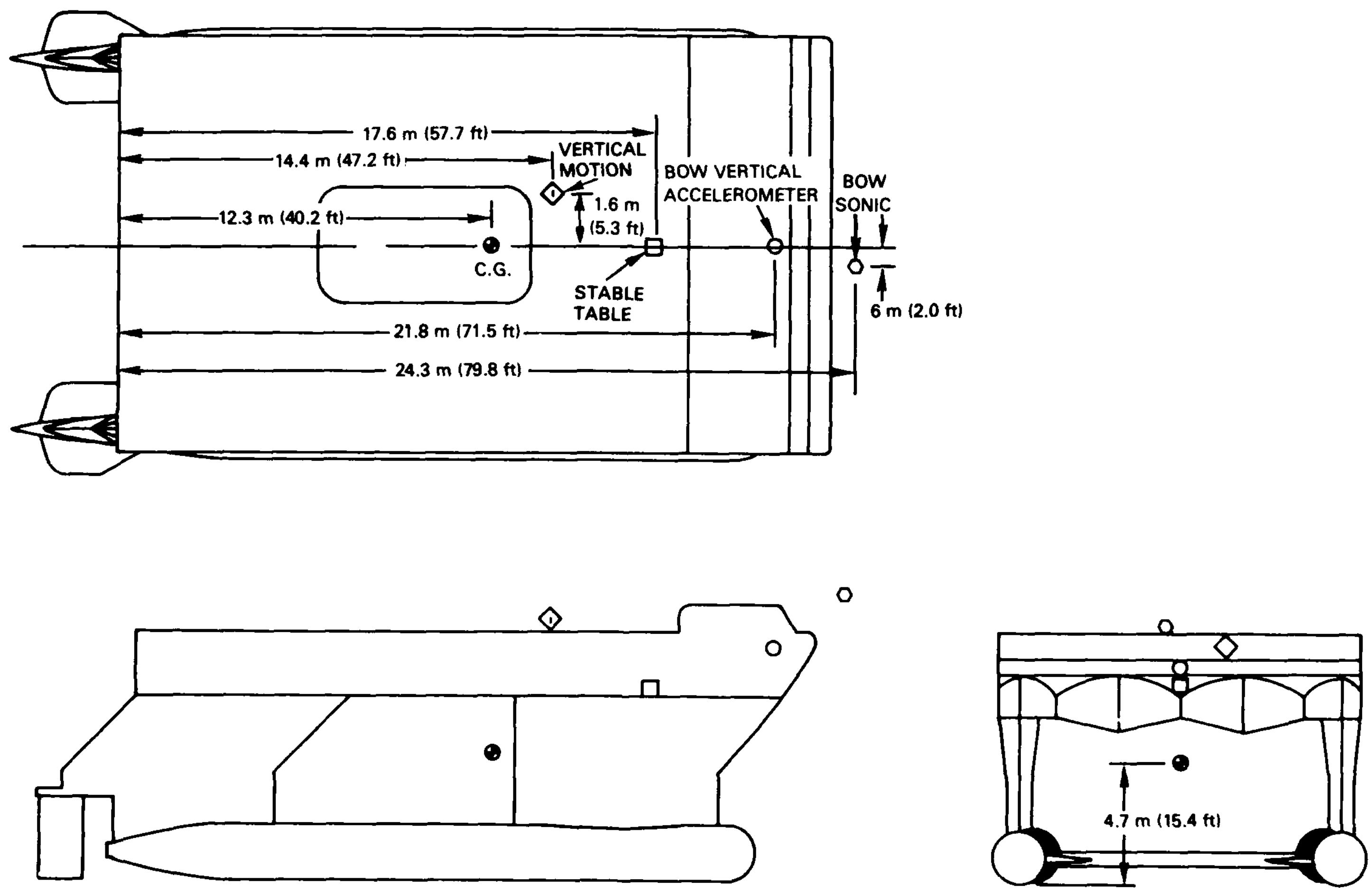

Figure 1 - SSP KAIMALINO Transducer Locations

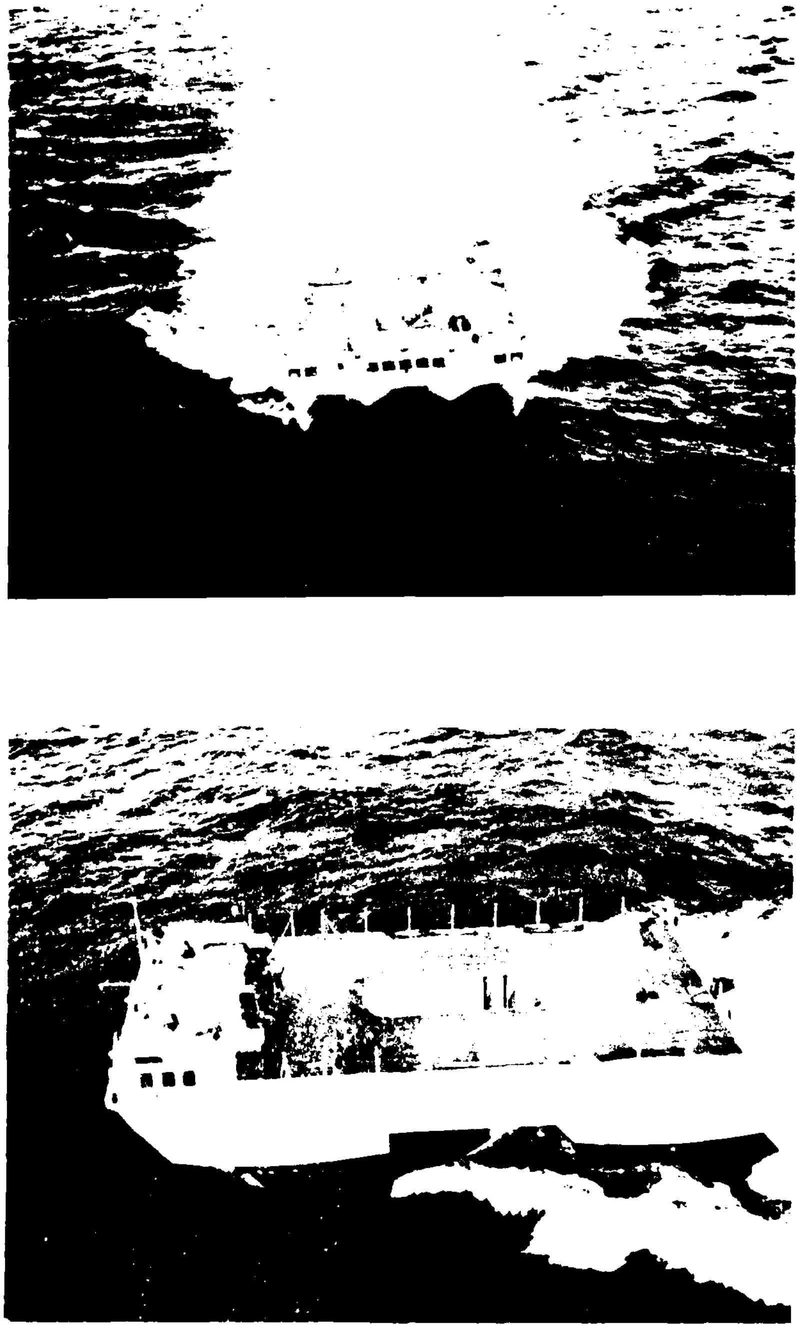

Figure 2 - SSP KAIMALINO Undergoing Trials Off Mokapu Point, Hawaii

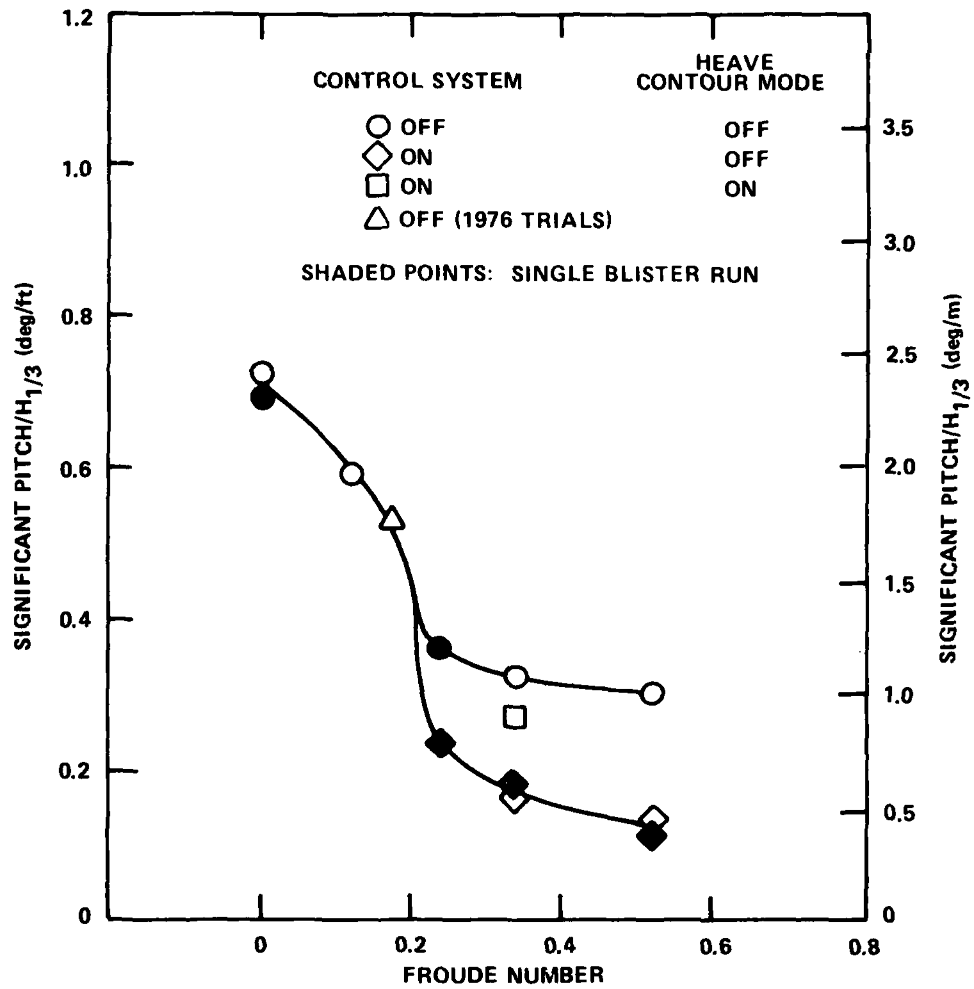

Figure 3 - Variation of Significant Pitch/Significant Wave Height with Froude Number for 1979 and 1976 Trials of the SSP KAIMALINO in Head Seas

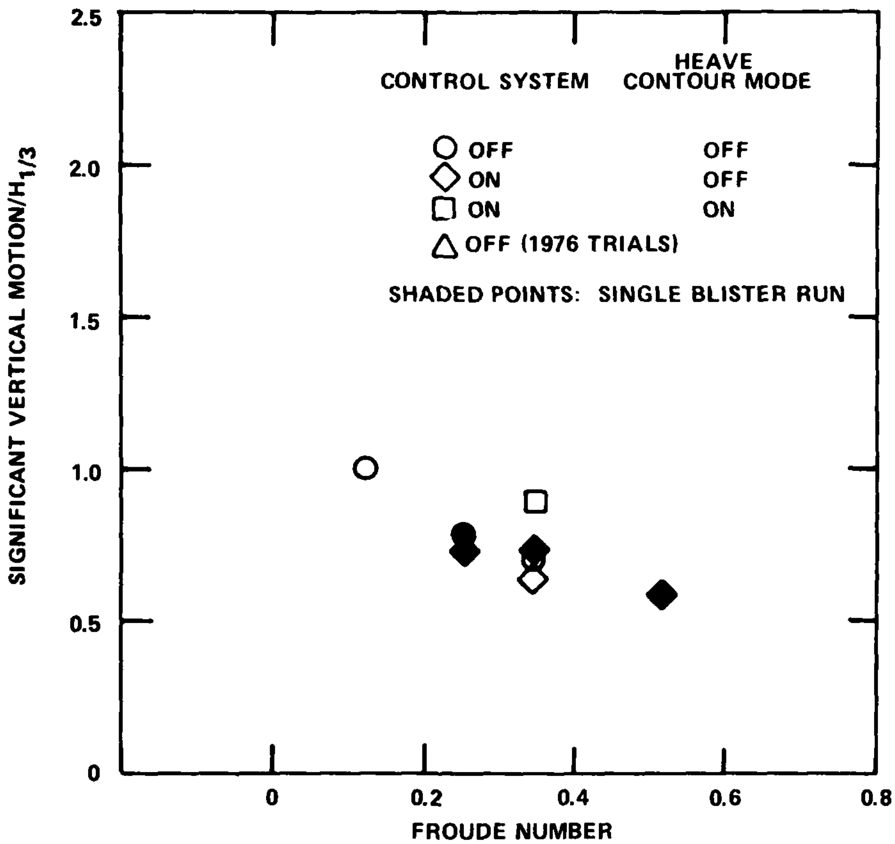

Figure 4 - Variation of Significant Vertical Motion/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Head Seas

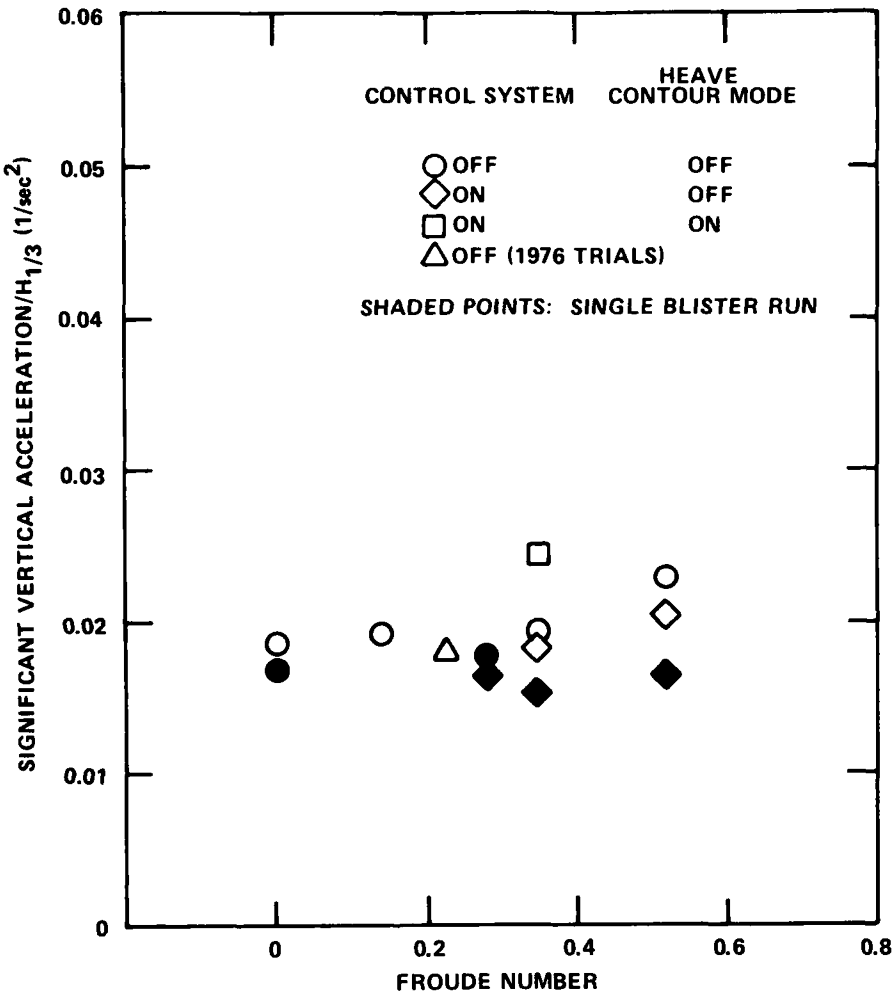

Figure 5 - Variation of Significant Vertical Acceleration/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Head Seas

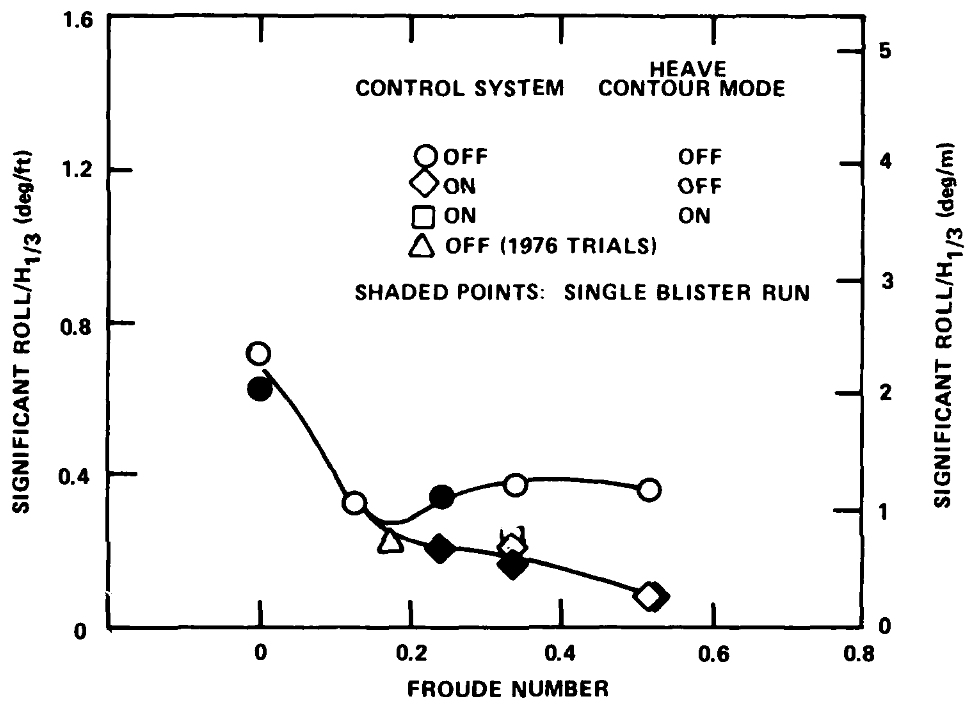

Figure 6 - Variation of Significant Roll/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Head Seas

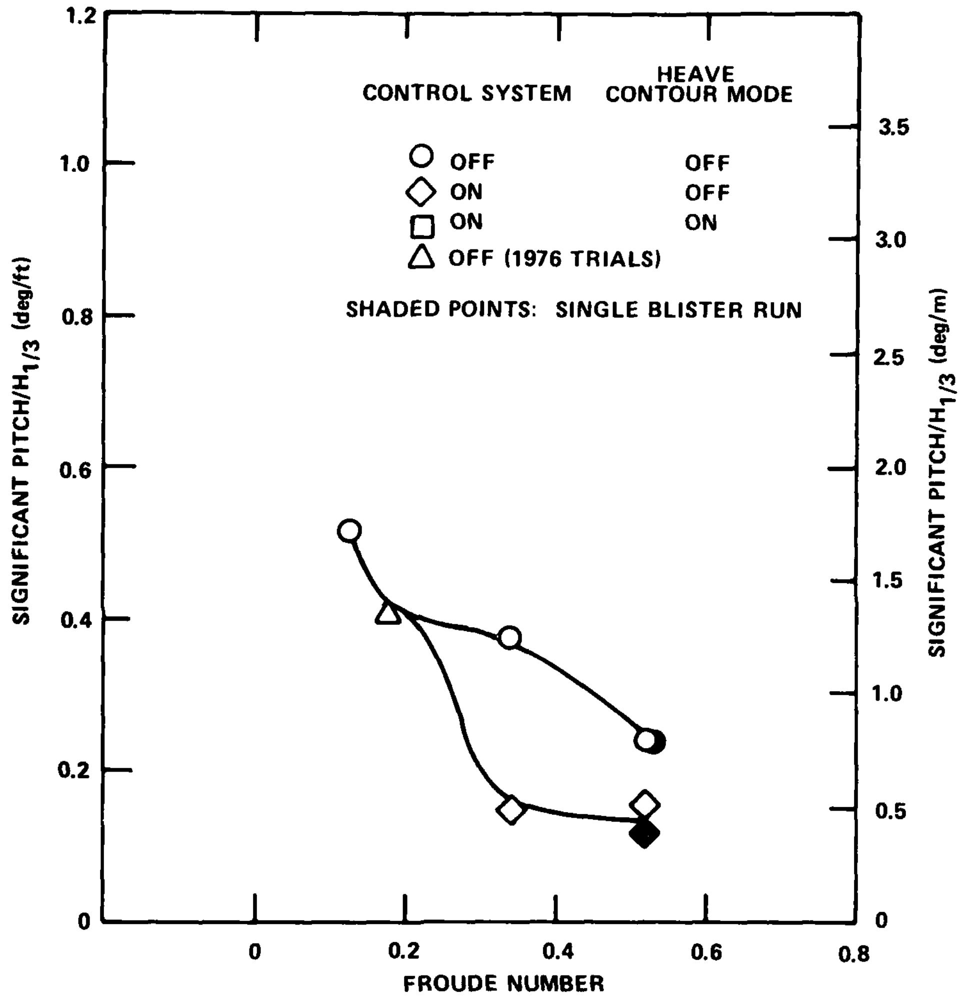

Figure 7 - Variation of Significant Pitch/Significant Wave Height with Froude Number for 1979 and 1976 Trials of the SSP KAIMALINO in Bow Seas

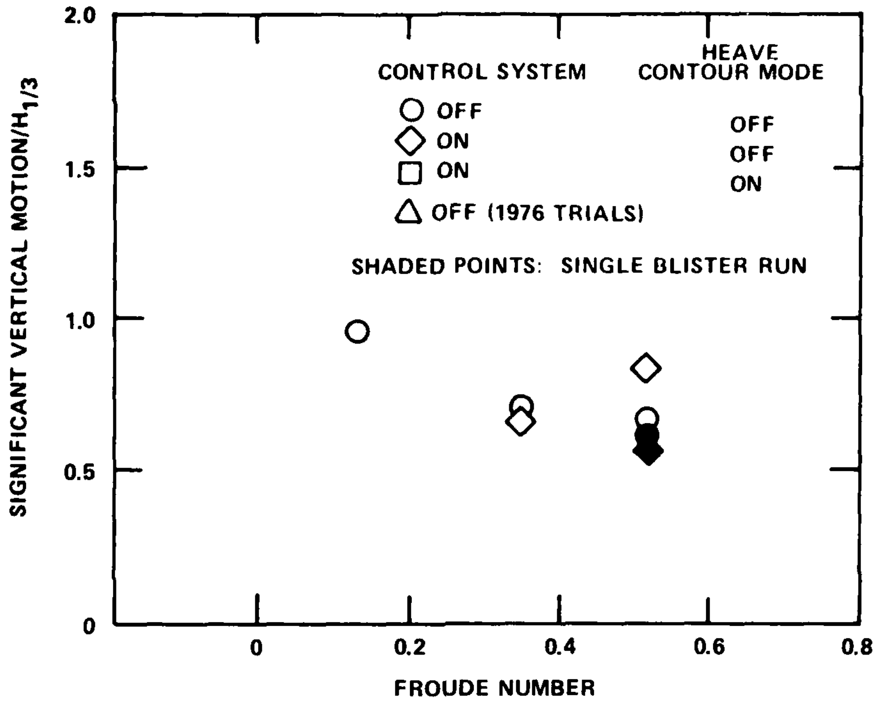

Figure 8 - Variation of Significant Vertical Motion/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Bow Seas

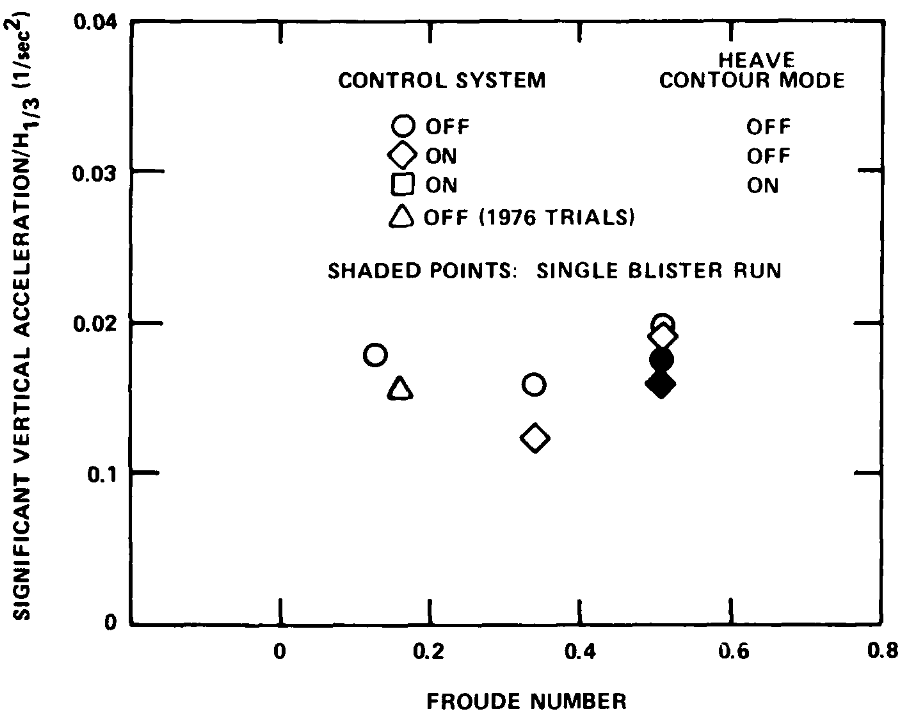

Figure 9 - Variation of Significant Vertical Acceleration/ Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Bow Seas

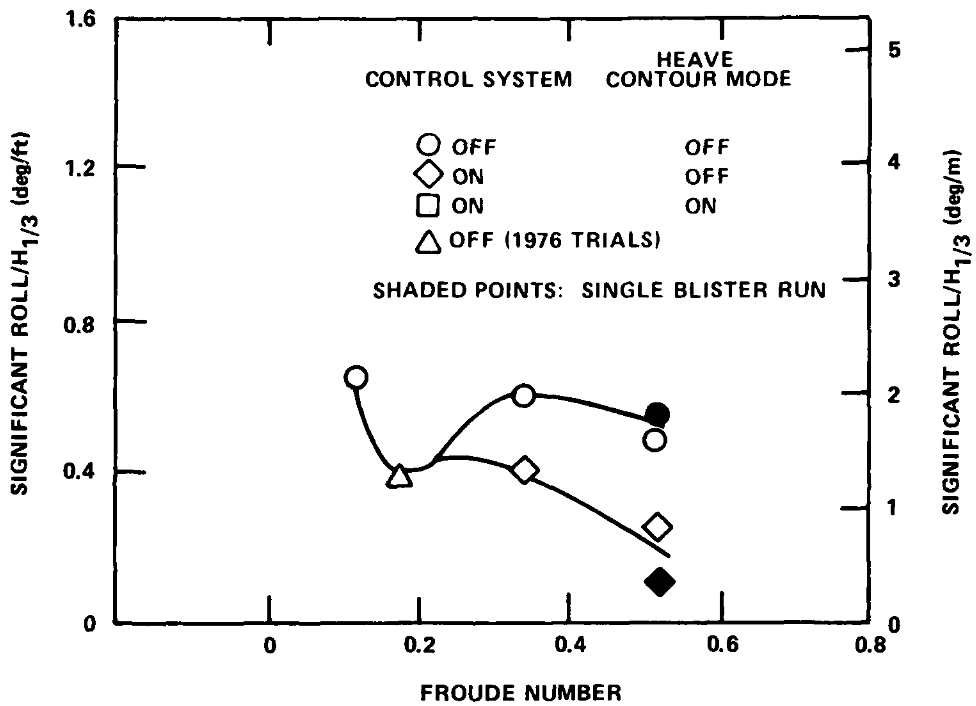

Figure 10 - Variation of Significant Roll/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Bow Seas

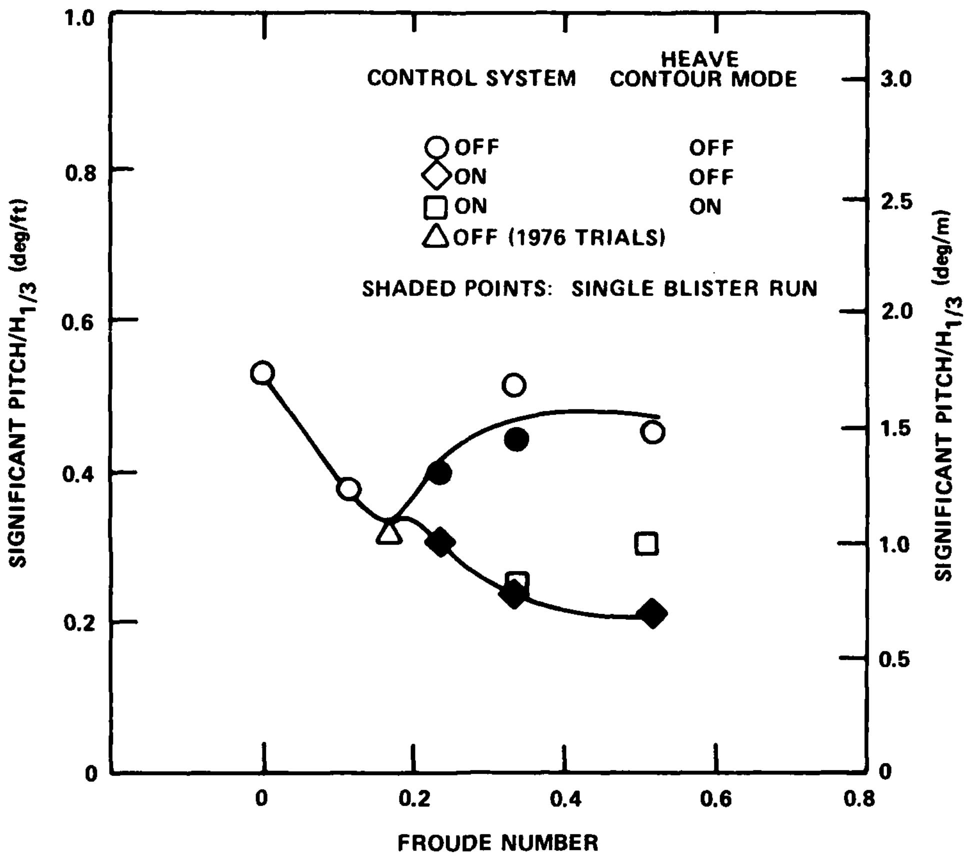

Figure 11 - Variation of Significant Pitch/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Beam Seas

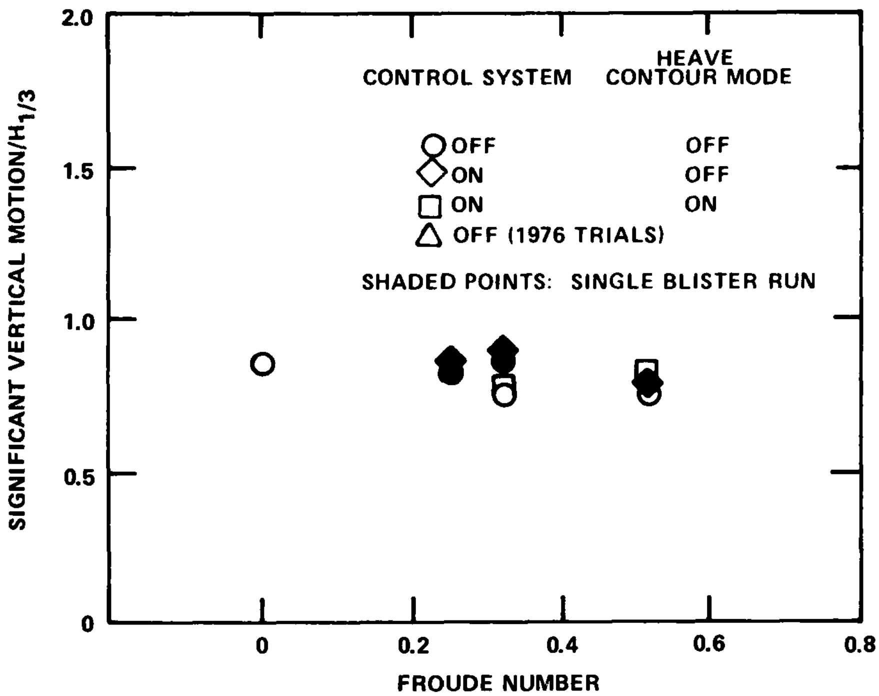

Figure 12 - Variation of Significant Vertical Motion/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Beam Seas

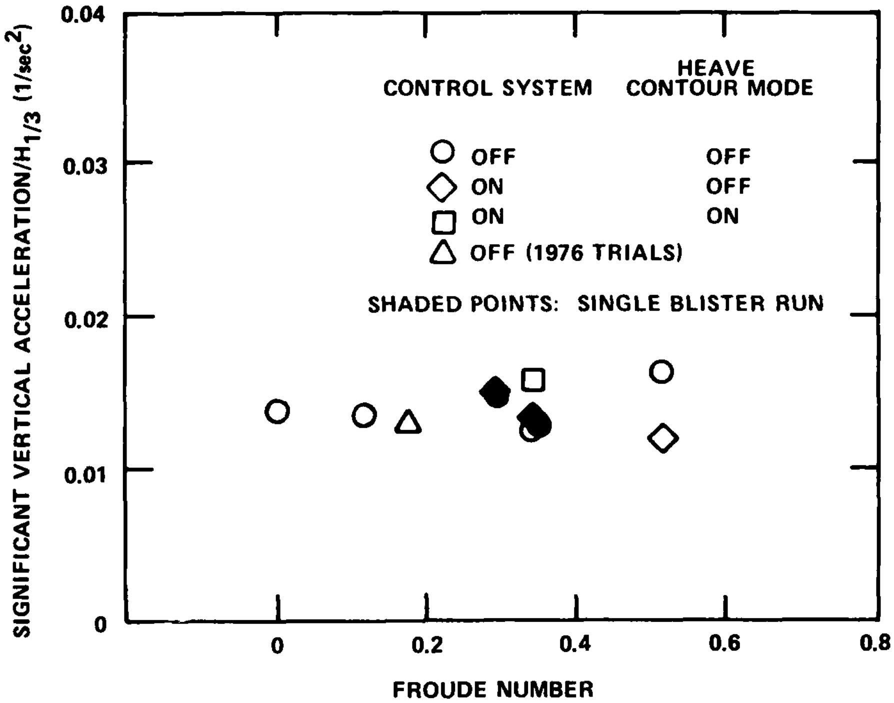

Figure 13 - Variation of Significant Vertical Acceleration/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Beam Seas

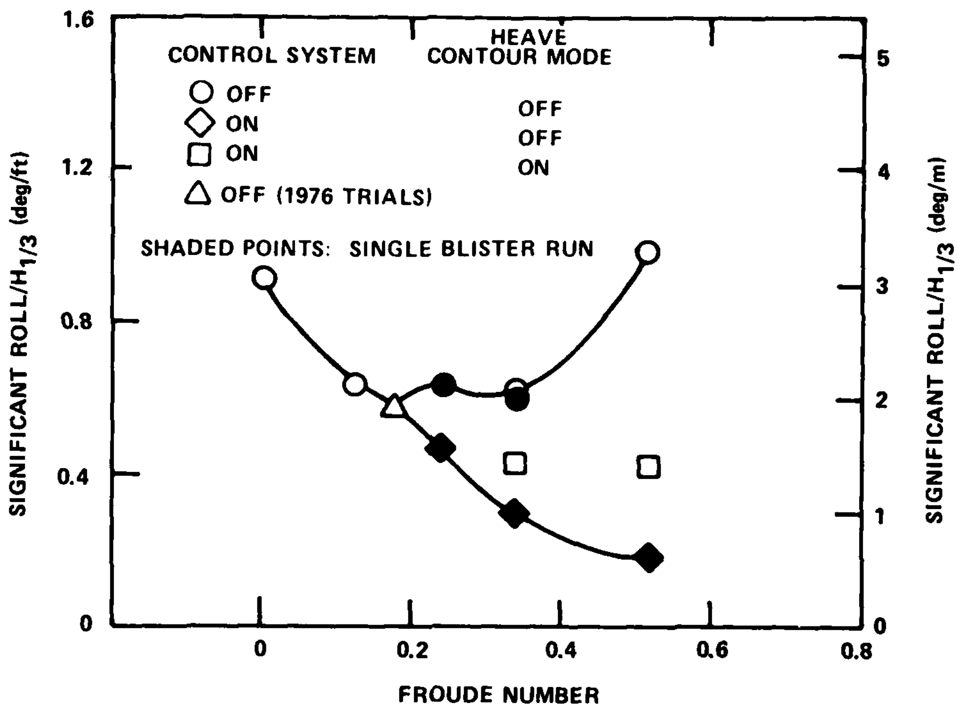

Figure 14 - Variation of Significant Roll/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Beam Seas

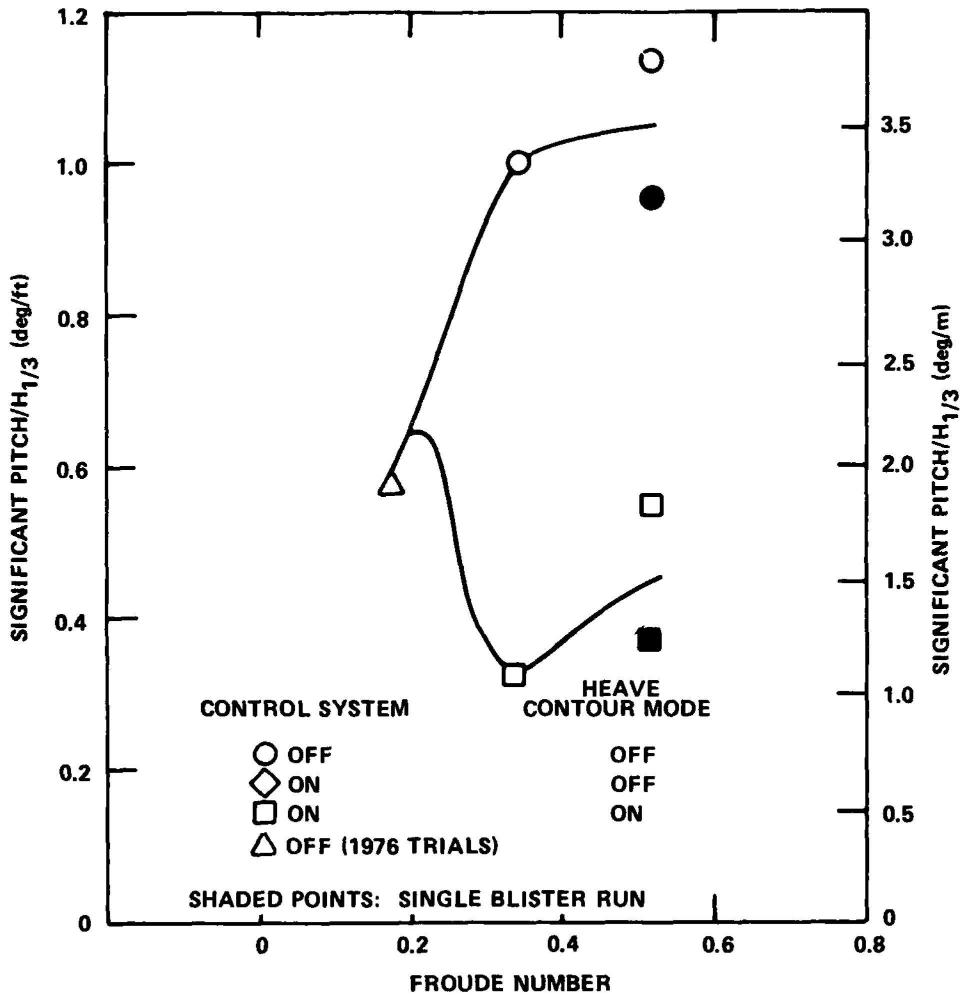

Figure 15 - Variation of Significant Pitch/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Stern Quartering Seas

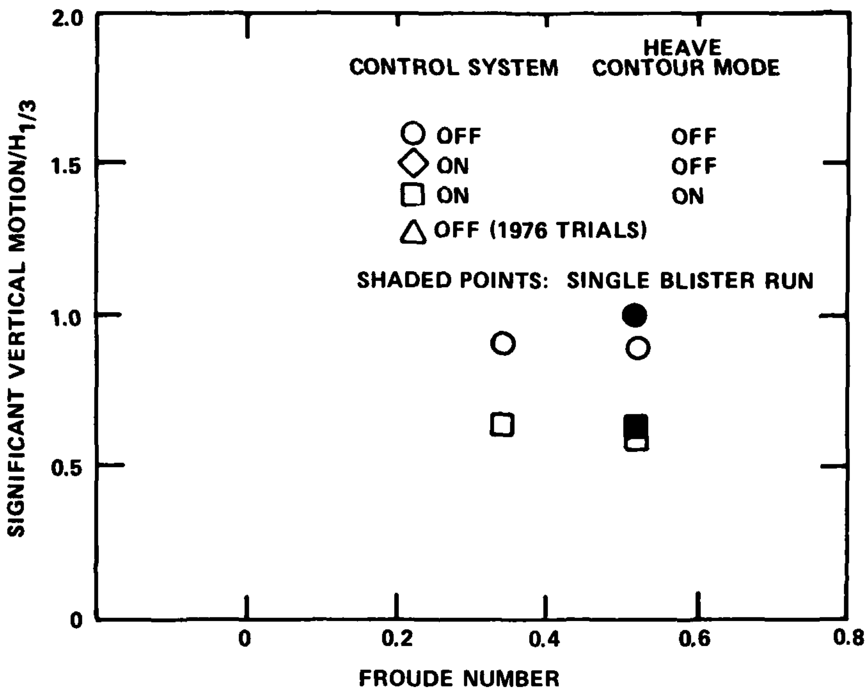

Figure 16 - Variation of Significant Vertical Motion/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Stern Quartering Seas

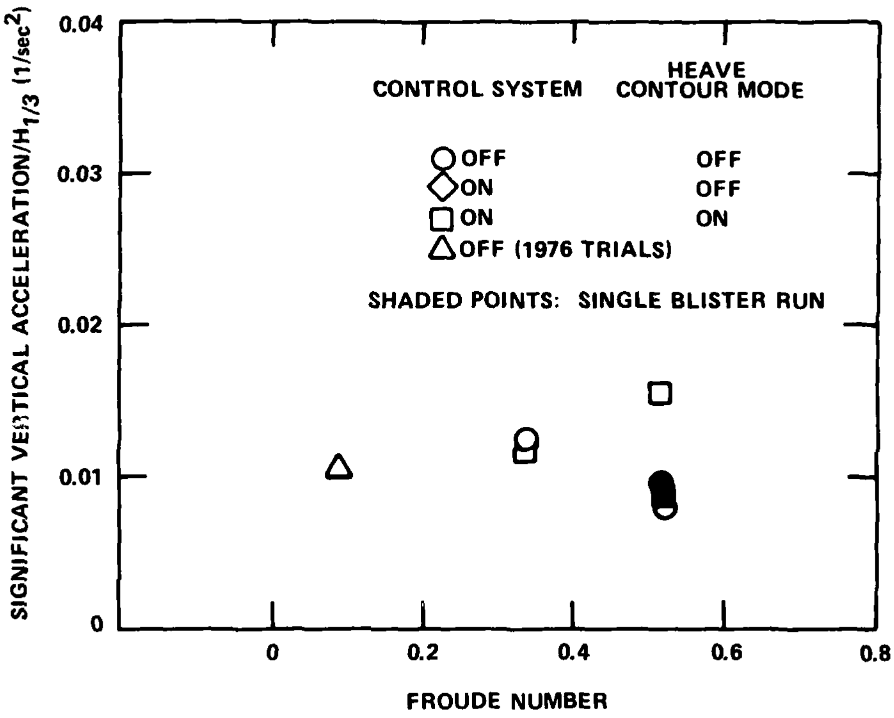

Figure 17 - Variation of Significant Vertical Acceleration/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Stern Quartering Seas

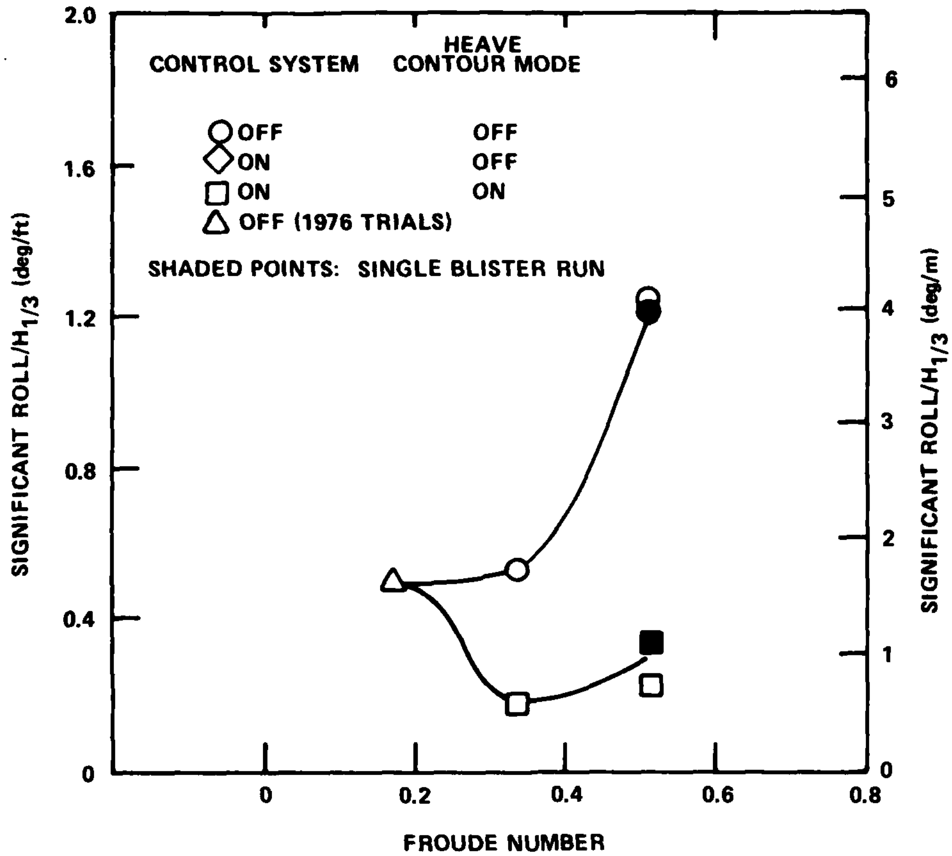

Figure 18 - Variation of Significant Roll/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Stern Quartering Seas

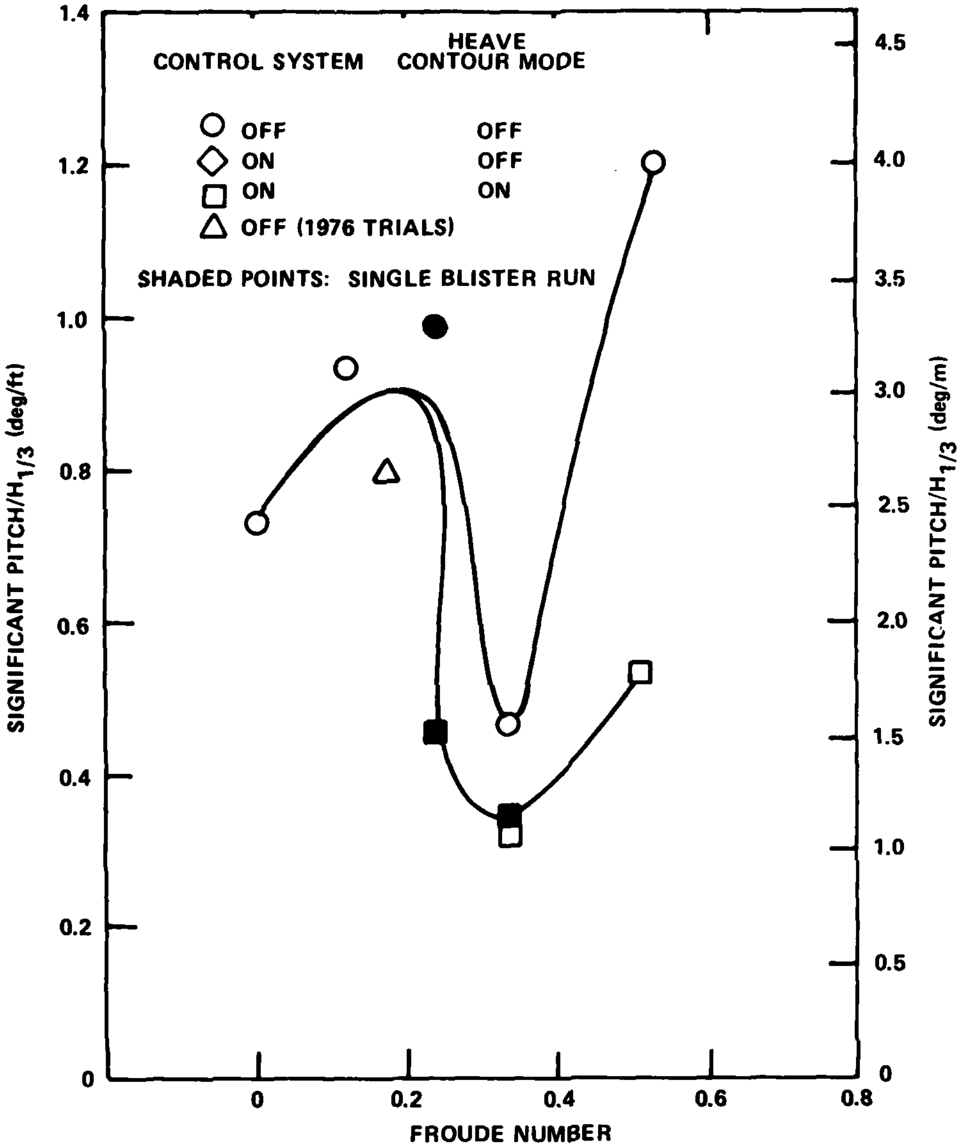

Figure 19 - Variation of Significant Pitch/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Following Seas

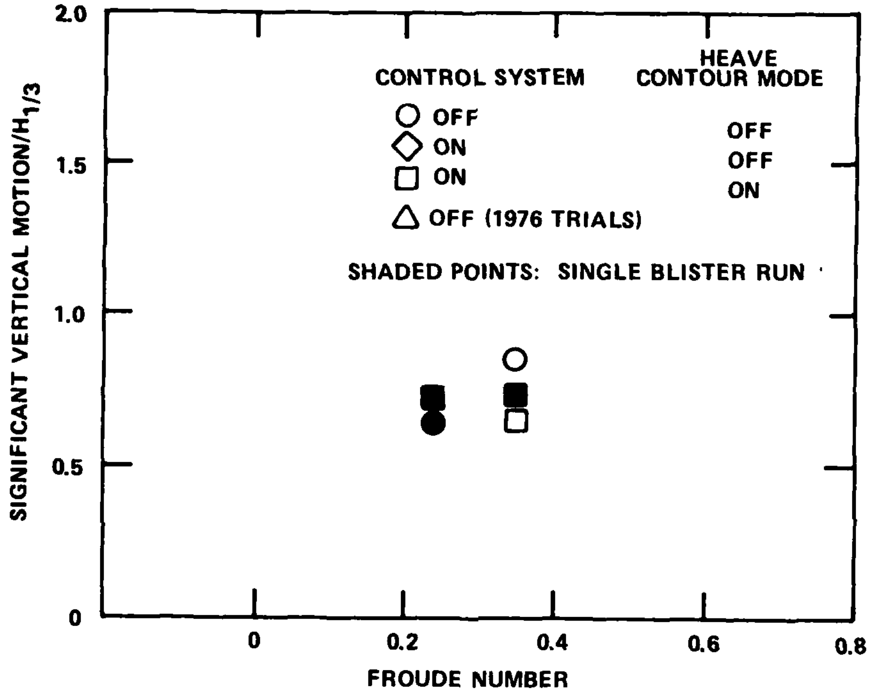

Figure 20 - Variation of Significant Vertical Motion/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Following Seas

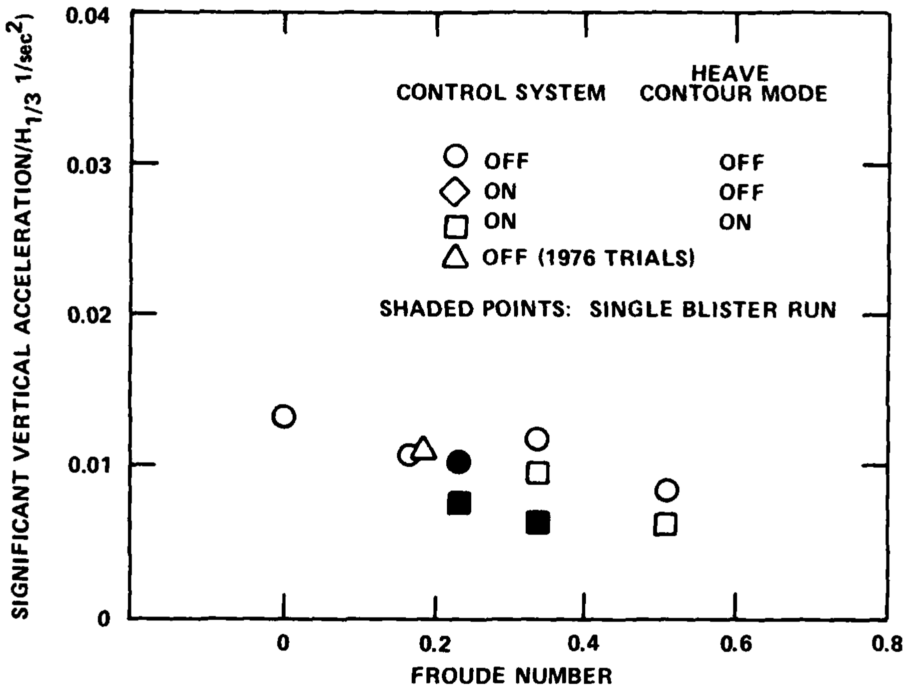

Figure 21 - Variation of Significant Vertical Acceleration/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Following Seas

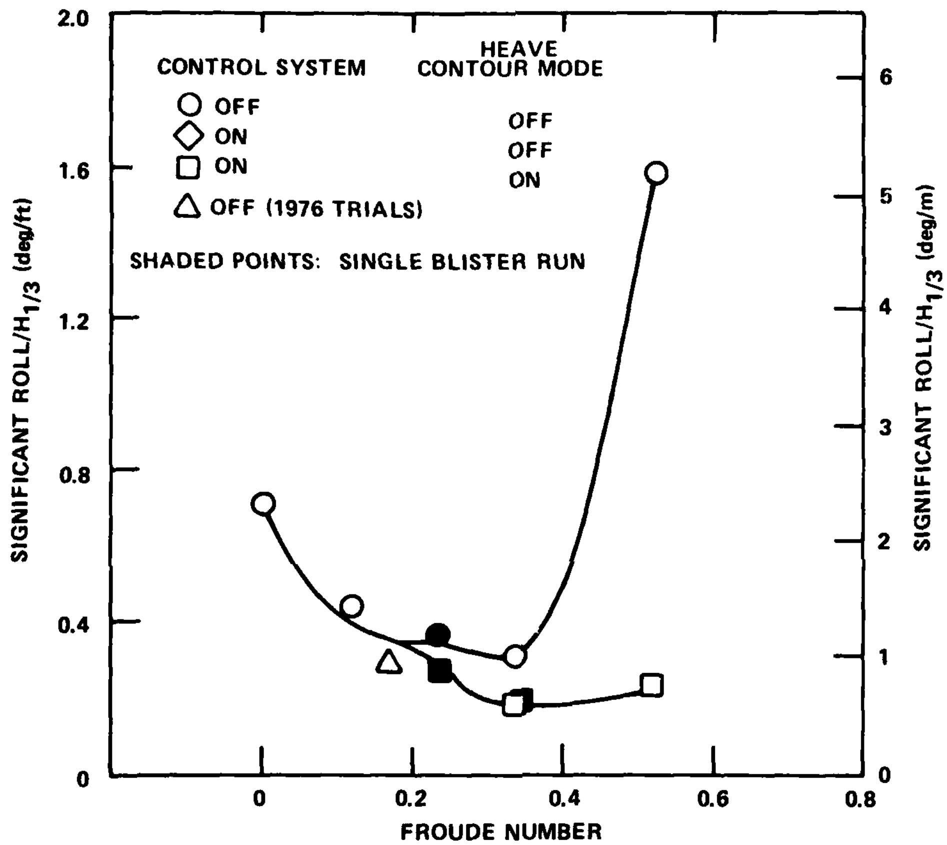

Figure 22 - Variation of Significant Roll/Significant Wave Height with Froude Number for 1979 and 1976 Trials of SSP KAIMALINO in Following Seas

TABLE 1 - GEOMETRIC CHARACTERISTICS OF SSP KAIMALINO

Overall Length	88.2 ft	26.9 m
Submerged Length, Nose to Trailing Edge of Rudder (AP)	81.2 ft	24.8 m
Submerged Maximum Beam	49.7 ft	15.1 m
Displacement, Salt Water	217.5 long tons	220.0 metric tonnes
KG, Height of Center of Gravity (CG) Above Baseline	15.4 ft	4.7 m
Longitudinal Distance, AP to CG	42.4 ft	12.9 m
Draft, Mean Design	15.2 ft	4.6 m

TABLE 2 - SUMMARY OF TRIALS AND MEASURED AND PREDICTED EXPERIMENTAL CONDITIONS

Date	Draft		Number of Runs	Wind Speed		Wind Direction		Significant Wave Height				Sea State	Modal Period Actual
				Predicted	Actual	Predicted	Actual	Predicted		Actual			
	m	ft		knots	knots	deg	deg	m	ft	m	ft		sec
1/21/79	4.8	15.8	10	21	35	077	060	3.0	9.9	2.9	9.6	5	9.8
1/23/79	4.7	15.4	4	16	20	072	060	3.4	11.2	2.5*	8.3*	4	9.5 and 9.1
1/25/79	4.6	15.2	18	10	15	069	070	2.1	6.9	2.0	6.6	4	9.5
1/31/79**	5.1	16.8	19	11	15	094	080	3.0	9.9	3.2	10.6	5	10.3

*Shielded by islands from predicted large swell component.

**No port blister on this day.

TABLE 3 - TRIALS RUN MATRIX

Speed knots	Headings* deg	Motion Control	Sea States	Trial Date
0	000, 000	No Control	5	1/21
	180	No Control	5	1/31
	180	No Control	4	1/23
3.5	000, 090	No Control	5	1/21
	135, 180	No Control	4	1/25
7	000, 090, 180	No Control and Controlled	5	1/31
10	000, 090, 180	No Control and Controlled	5	1/31
	000, 045, 090, 180	No Control and Controlled	4	1/25
	135	No Control and Controlled	4	1/23
15.5	000, 090, 180	No Control and Controlled	5	1/21
	045, 090, 135, 180	No Control and Controlled	5	1/31
	045, 135	No Control and Controlled	4	1/25

*000 is following sea.

REFERENCES

1. Stenson, Richard, "Full-Scale Powering Trials of the Stable Semi-Submerged Platform, SSP KAIMALINO," DTNSRDC Report SPD-650-01 (Apr 1976).

2. Fein, James A. and Robert T. Waters, "Control Response Trials of the Stable Semi-Submerged Platform (SSP KAIMALINO)," DTNSRDC Report SPD-650-02 (Apr 1976).

3. Kallio, James A., "Seakeeping Trials of the Stable Semi-Submerged Platform (SSP KAIMALINO)," DTNSRDC Report SPD-650-03 (Apr 1976).

4. Fein, James A., "Low Speed Seakeeping Trials of the SSP KAIMALINO," DTNSRDC Report SPD-650-04 (Nov 1977).

5. Lang, T.G. et al., "Design and Development of the 190 Ton Stable Semi-Submerged Platform (SSP)," Journal of Engineering for Industry (Nov 1974).

6. Higdon, D.T., "Active Motion Reduction on SSP KAIMALINO in a Seaway," AIAA/SNAME Advanced Marine Vehicles Conference Paper No. 78-740, San Diego, Calif. (Apr 1978).

7. Fein, J.A. et al., "The Seakeeping Characteristics of a Small Waterplane Area, Twin-Hull (SWATH) Ship," 13th ONR Symposium on Naval Hydrodynamics (1980).

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